Dielectric metasurfaces for flat optics: wavefront engineering and future display and security applications

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Miniaturization is a main stream in modern technology, but reduction of conventional optical components accompanies performance degradation that limits the minimum feature size of optical devices. Metasurfaces that consist of ultrathin subwavelength antenna arrays can be a promising solution because metasurfaces provide an effective way of wavefront engineering without constraints on the device size[1]. Electromagnetic responses of individual building blocks are determined by its geometric configurations, and many kinds of antennas have been explored to clarify the capability of metasurfaces; thereby, it has been verified that dielectric antennas can control amplitude[2], phase[3], and even both of them simultaneously[4,5,6].

The capability of wavefront engineering allows to realize versatile future applications such as holograms, lenses and color filters. Fundamental limitations of conventional holograms such as twin image and narrow viewing angle can be removed by metaholograms due to their sub-wavelength pixel size. Propagation phase of isotropic building blocks enables polarization-insensitive operation[3] while geometric phase of anisotropic building blocks allows broadband operation of multifunctional metaholograms (*i.e.* image hologram, multiplexed metaholograms)[7-11]. Furthermore, both propagation phase and geometric phase can be considered in design of meta-atom, which enables a multicolor metahologram[12] and complex-amplitude hologram[6]. The recent advanced understanding of building blocks brings about an increase of the number of hologram encoded in the metasurface based on dispersion engineering[12] and orbital-angular-momentum multiplexing[6]. The metaholograms can also be extended to random point-cloud generation for application toward 3D object detection[13]. The same design method described above can be applied to polarization independent broadband beam splitting[14] and ultrathin light-focusing devices, *i.e.* metalenses[15,16,17].

Metasurfaces can engineer transmission/reflection spectrum in visible regime, i.e. sub-wavelength color printing. The building block to modulate scattering response is high-index dielectric Mie-scatterer which resonantly radiate light with fundamental modes when its size become comparable to wavelength of incident light. The metasurface, composed of arrays of Mie-scatters, transmit/reflect lights with the resonance modes, thus rendering structural colors which are changed according to the geometry of the scatterers[18,19]. The metasurface which consists of asymmetric unit structure switch its colors depending on the polarization state of incident light, thus enabling application for optical cryptograpy[2,20,21]. Adoption of phase change materials and stimuli-responsive materials enables active color filters[22,23,24].

Comprehensive metasurfaces that control both phase and amplitude have been realized by adjusting unit structures. The hologram resolution can be drastically improved by controlling complex amplitude using X-shaped antennas[4], and both functions of holography and color printing can be integrated in a single metasurface[5].

Recently, much metasurface research has aimed to embed nanoparticle-based hierarchy in building blocks to enhance the chirality[25] and refractive index[16,17,26]. Furthermore, actively tunable meta-holographic displays with designer liquid crystal modulators will enable interactive holographic displays and unconventional photonic sensor applications[27,28,29]. In the future, with supported by further materials development[30] and system integration, metasurface research will be further expanded to a practical region by exploiting diverse light properties (*e.g.* orbital angular momentum) to realize real-time 3D holographic video displays or advanced optical security labels[6].

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